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(54) AUTOMOTIVE BATTERY STATUS MONITOR.

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method and apparatus for automatically testing, monitoring and maintaining a motor vehicle starting system and more particularly to a system by which the condition of the vehicle storage battery, as well as the low temperature starting limit, maintenance requirements and service life thereof can be monitored.

2. Description of the Prior Art

Systems for determining one or two of such battery conditions as battery capacity, state of charge, defects in the battery and the charging system, maintenance requirements and timely indication of the need to replace the battery or alternator/regulator, have been developed to facilitate maintenance of a reliable and safe motor vehicle. Manual determination of these parameters is expensive, time consuming and often has to be conducted at service stations. With the introduction of microprocessors, the battery characteristics, engine starting requirements and operational characteristics of a vehicle can be determined automatically, providing optimum life and safety performance for vehicle components.

Automotive batteries provide power for the vehicle's starting, lighting and ignition (SLI) components of the car. Of these, the starter motor requires the most power and is the first component affected by a weakened SLI battery. The necessity for determining when the battery is on the verge of losing its ability to provide the required power is readily apparent. Such a determination is arrived at by a skilled mechanic during testing of the battery and the charging system at a garage, or by means of a monitoring device located in the vehicle. The latter is advantageous in that it is more convenient and provides timely and unbiased advice.

Generally, the automotive battery puts out a few hundred amperes of current for a few seconds of the starting period, the actual amperage being dependent on the battery capacity and its state of charge, and on design and size of the automotive engine and starter motor. The battery is then recharged by the charging system of the vehicle, which consists of an alternator, rectifier, regulator, voltage and current controllers, typically in several minutes.

Several conditions of component status can cause starting failure of a vehicle. These are: Low state of charge of the battery, loss of the battery capacity, corroded terminals, low level of the electrolyte defective charging system and defective starter motor. A battery status monitor should function to sort out these problems automatically. The monitor should diagnose a problem as it develops and warn the user in advance of imminent failure. However, battery monitors heretofore disclosed do not identify each of the aforementioned problems; most of them attempt to determine only the state of charge of the battery.

Battery monitors originally comprised merely an ammeter and/or a voltmeter located on the dashboard of the vehicle. They provided limited information of a type useful only to knowledgeable drivers. To have the battery tested, the car was garaged, the battery was disconnected from the vehicle's electrical system by a skilled mechanic and discharged through a known load. Alternatively, monitoring instruments were employed to derive the battery status parameters using an a.c. signal without discharging the battery through a load. Such monitoring instruments require that the battery be disconnected from the electrical circuitry of the car. Even then they provide information about the state of charge solely.

Conventionally, the state of charge of the battery has been determined by measuring specific gravity of the electrolyte. This method is predicated on the fact that the specific gravity of the sulfuric acid electrolyte decreases when the battery-is discharged and increases when the battery is charged. Normally, the specific gravity of the battery electrolyte ranges from about 1.28 - 1.30 when the battery is fully charged. Such a method is laborious and cannot predict loss of battery capacity in advance. Furthermore, such problems as corroded terminals are not detected by this method.

An alternative method for determining the state of battery charge involves the continuous counting of charge into and out of the battery. This method is subject to accumulation of error due to the current consumed by gassing in the battery and changes in battery capacity arising from corrosion of the electrode plates and shedding of active material. A device of this type, using a current to frequency converter, is described in U.S. Patent No. 4,678,999 to J.F. Schn id r.

A battery's maximum power output is determined by its voltage and internal impedance. Generally the internal impedance of the battery increases with the lif of the batt ry and with a decreas in its stat of charge. In U.S. Patent No. 4,678,998 to Muramatsu, ther is described a device based on this principle. According to

Muramatsu, th relationship between battery impedanc , remaining capacity and remaining service life is predetermined at differ nt frequenci s and stored in memory. To determine th battery condition, a computer evaluat s th internal imp danc at a few frequ ncies and looks up to th stored tabl of pred t rmin d values to obtain th remaining servic lif f the battery. Such a device is subject to the drawback that each battery or battery group has to be subjected to tests before installation to generate the table of predetermined values.

US-A- 4 665 370 describes a battery monitor wherein a cranking motor furnishes the load for the battery and an electronic apparatus automatically measures the condition of the battery each time the engine is started. The battery monitor compares the unloaded battery voltage with the voltage under load and indicates that the battery is bad if the voltage differential exceeds a predetermined limit. One disadvantage of this device is the inability thereof to distinguish between a low state of battery charge, a fully charged battery having low capacity and additional faulty conditions of the battery such as corroded terminals or low electrolyte level.

DE-A-3712629 discloses an automobile charge system comprising an alternator driven by an internal combustion engine and a battery charged by the alternator; with an automotive battery life diagnosis apparatus comprising means for detecting the terminal voltage of the battery, means for detecting the charge-discharge current of the battery, means for detecting the temperature signal correlated with the battery, and a controller for processing inputs from the detection means; and including:

means for obtaining an initial internal resistance of a battery, based on a battery voltage and a charge-discharge current before and after a first cranking under the fully charged condition of the battery, and fixedly memorizing at least the initial internal resistance;

means for obtaining a second internal resistance while using the battery, based on a battery voltage and a charge-discharge current before and after cranking, and temporarily memorising the second internal resistance;

means for obtaining a resistance ratio of the initial internal resistance and the second internal resistance and means for comparing the resistance ratio with a battery life ratio which indicates the life state of a predetermined battery to judge the life state of the battery under test; and

means for displaying the result.

The present invention provides a method and apparatus for monitoring a vehicle storage battery to determine certain conditions, including defects and characteristics, of the battery. Generally stated, the apparatus comprises a microprocessor means located on the vehicle for controlling the operations of the apparatus. A software means instructs the microprocessor means to control the sequence of the operations. Memory means are connected to the microprocessor means for storing the software instructions and predetermined relationships between the internal resistance of said battery, the tolerable limit of the internal resisitance and the ambient temperature of the battery.

A digital to analog converter means is connected to the microprocessor means for converting digital signals from the microprocessor means to analog signals. The digital to analog converter means has connected thereto a direct current power generator means for producing electric power at voltage and current required by the microprocessor means. A current sensor means, connected to a terminal of the battery measures the current passing into and out of the battery. The ambient temperature of the battery is measured by a temperature sensor means, located in close proximity thereto. A voltmeter means measures the voltages of the battery, current sensor, temperature sensor and direct current power generator means. Connected to the voltmeter is an analog to digital convertor means for converting the analog signals from the voltage measurements into digital signals appointed for transfer to the microprocessor. A second software means analyzes the current, voltages and temperature, and determines the internal resistance (I_R) and polarization resistance (P_R), of said battery, determines the state of charge of said battery as a function of open circuit voltage (OCV) excluding polarization effects, detects possible corroded terminals from the determined state of charge and internal resistance (calculated according to equation (2) set out below,), and detects possible low electrolyte level as a function of polarization resistance (calculated according to equation (3) set out below) and state of charge, whereby internal resistance of the battery is determined from the instantaneous change in voltage at the beginning or at the end of a current input to or current output from the battery, which instantaneous change in voltage is caused by switching on or switching off charge current to or discharge current from the battery, and the polarization resistance of the battery is determined from a change in voltage during a predetermined time interval immediately following the instantaneous change in voltage. This second software means also determines a low temperature starting limit by comparing the battery's power output capability, determined as a function of the calculated internal resistance, with the prevailing power requirements of the vehicle component system including the starting system and taking account of the temperatur of the system. The apparatus has an actuator means for controlling the electrical circuits connecting the sensors, the direct current power generating means and the batt ry. A display means, controlled by the microprocessor, indicates said battery status and advice.

In addition, th invention provides a method for monitoring a vehicle storage batt ry, which comprises the

steps of operating the above defined apparatus to:

(a) measure continuously the ambient temperatur , the battery voltage, th output voltage of a power sourc attached to said batt ry, and th current to and from said batt ry;

(b) analyze said current-voltag (I-V) data to determine the internal resistanc and polarization resistance of said battery, whereby said internal resistance of said battery is determined from the instantaneous change in voltage at the beginning or at the end of a current input to or current output from the battery, which instantaneous change in voltage is caused by switching on or switching off charge current to or discharge current from said battery, and said polarization resistance of said battery is determined from a change in voltage during a predetermined time interval immediately following said instantaneous change in voltage;

(c) determine the state of charge of said battery as a function of open circuit voltage excluding polarization effects, determining possible corroded terminals as a function of said state of charge and said internal resistance according to the above-mentioned relation (2), and determining possible low electrolyte levels function of said polarization resistance according to the above-mentioned relation (3) and said state of charge;

(d) determine the low temperature starting limit by comparing said battery's power output capability, determined as a function of the determined internal resistance with the prevailing power requirements of said vehicle component system including the starting system and taking account of said ambient temperature; and

(e) indicate data produced by said comparison.

An embodiment of the method provided by this invention for monitoring the condition of and providing status and advice concerning the vehicle storage battery comprises the steps of:

(a) subjecting the battery to a special test cycle wherein a predetermined profile of current or voltage is imposed onto the battery by the charging system and the battery response voltage or current is measured;

(b) evaluating the data in the forms, dV/dI versus I, or dI/dV versus V;

(c) determining the battery characteristics, including the capacity, and the voltage as a function of the current and voltage data provided by step (a);

(d) determining the battery defects, including mismatched cells as a function of the corresponding values of current or voltage at which the battery starts evolving gas during the test of step (a), and soft-shorted cells or sulfated cells both as a function of the imposed current; and

(e) indicating said data and advice.

A battery status monitor made using the method and apparatus of this invention can determine the present battery capacity, state of charge and fault conditions. When the battery is in a predetermined range of its state of charge near its fully charged status, the monitor can cut out the alternator through a clutch, thereby enhancing the gas mileage. When the state of charge is below a set limit, or the accessory current drain is above a preset limit, or the ambient temperature is below a preset limit, the power source is kept operational.

An important feature of this invention is its capability to indicate the low temperature starting limit of the car together with the battery's present conditions. The monitor arrives at a number for the low temperature limit by taking into account both the engine starter motor requirements and the battery's ability to meet them.

An important advantage of this invention is that the monitor can offer unbiased advice to the user concerning the decision whether to maintain or to replace the battery. This monitor, by evaluating the values of the internal resistance and the polarization, is capable of indicating whether the terminals need cleaning or the battery needs water. Upon detecting conditions such as the presence of (i) one or more bad cells (low capacity mismatched cells or soft-shorted cells), or (ii) high internal resistance in the absence of any other defects, the monitor indicates the need to change the battery.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood and further advantages will become apparent when reference is made to the following detailed description of the preferred embodiments of the invention and the accompanying drawings, in which:

Figure 1 is a block diagram showing the battery status monitoring apparatus of the invention in conjunction with other components of a motor vehicle starting system;

Figure 2 is a flow diagram of a preferred embodiment of this invention;

Figure 3 is a schematic circuit diagram for testing th battery status monitor;

Figure 4 is a graph depicting curr nt voltage characteristics of an automotiv battery during a sudden discharge and immediate recharg occassional by starting of a motor vehicl ;

Figure 5 is a graph depicting th battery int rnal resistance and the maximum allowable limit of internal

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resistance as a function of temperatur for a 525 CCA battery;

Figure 6 is a graph showing the temperature dependence of battery requirements and battery performanc r lative to their respectiv values at room temperature (26.6°C];

Figur 7 is a block diagram showing the method for detection of gas point by current ramping t chnique; and

Figure 8 is a graph depicting battery capacity versus the current at which the battery starts evolving gas.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings, there is illustrated in Figure 1 a block diagram of the battery status monitor of this invention in conjunction with some of the other components of the motor vehicle starting system. A microprocessor 100, located on the vehicle for controlling the operations of the apparatus, has ROM and RAM memory for storing software, which instructs the microprocessor on the sequence of operations. The memory also stores the predetermined relationships and data concerning the battery and the vehicle's starting system. The microprocessor is also connected to a digital to analog converter 102, which converts the digital signals 104 to analog signal and transmits the analog signal to the alternator/regulator 106. The alternator/regulator is connected to the battery 108 through a current sensing shunt 110 and to a voltmeter 112. The alternator/regulator is also connected to other components of the vehicle through the leads 114. A programmed current 116 or voltage is provided to the battery by the alternator/regulator. The battery's response voltage 118 or current is measured by the voltmeter which is also connected to other components of the vehicle, including the temperature sensor, through the leads 120. An analog to digital converter 122 attached to the voltameter converts the analog measurements to digital signal 124 and transmits the digital signal 124 to the microprocessor which is also connected to other components of the vehicle through the leads 126. The accessories and the starter motor, connected in parallel with the battery and the alternator/regulator, are shown in Figure 3.

The flow diagram illustrated in Figure 2 shows the sequential operations of the battery status monitor. As illustrated, the flow diagram applies to the test apparatus and the test circuit, of Figure 3, and is controlled by a multiuser microcomputer. For the commercial device to be installed in the automotive vehicles, steps 2, 21 and 22 may be eliminated without affecting the operations of the battery monitor; the microprocessor will execute step 3 instead of step 21, thus forming a continuous loop for the sequence of operations.

In step 1, all the variables are initialized. This step is executed only one time, when the device is installed in the car. The monitor then reads the values of all variables typically representing the characteristics of the car and the battery in step 2; this step is equivalent to step 21. It will be understood by those practicing the art that step 2 is not necessary in the commercial device since it will have a dedicated microprocessor with a continuous loop for the sequence of operations. In step 3, the monitor measures the ambient temperature (T), battery voltage (V), the power source voltage (V_s), current (I) using the shunt or other current sensing device, and real time(t). The power source in the test circuit, illustrated in Figure 3, is a power supply with voltage and current ratings equal to the output voltage and current of an automotive alternator/regulator. Hereafter, the combination of alternator, rectifier, voltage and current controllers will be referred to as the power source.

In step 4, the battery's state of charge is updated using a combination of the charge integration technique and the open circuit voltage (OCV). The first method based on OCV to determine state of charge (SOC) makes use of the fact that the open circuit voltage of a fully charged lead acid cell exhibits 0.2V higher than the OCV of a completely discharged cell. The cell voltage varies linearly in between these extremes. The voltage of a battery when no current is flowing into or out of the battery is normally referred to as the open circuit voltage. Since the automotive battery normally has six cells and a fully charged battery has 12.7 V or higher, the state of charge can be calculated as follows:

$$SOC = 100 - (((12.7 - OCV)/1.2) * 100) \% \quad (1)$$

The cell voltage used in this calculation should be free from polarization. The polarization normally arises from nonuniformity of the electrolyte concentration at or near the electrodes compared with the electrolyte concentration in the bulk. The voltage measured until several minutes after a charge or discharge invariably includes significant polarization voltage, even though there is no substantial current flowing from or to the battery.

The second method involves integration of the current that goes into and out of the battery at all times. The monitor starts counting the charge from a predetermined charged state of the battery. The total charge put into the battery from the power source is added to the stored charge of the battery, which is really the battery capacity to start with. Similarly the charge taken out of the battery during starting and by the accessories is subtracted from th stored charg . This net charg divided by the battery capacity gives the state of charge of the battery. Any time the monitor det cts that the battery is fully charged, it resets th state of charge to 100%. The fully charged state of th batt ry is recognized wh n the op n circuit voltage of the battery is above a predetermin d value, preferably 12.7 V. The fully charged status of the battery is also recognized through

th test cycl of the batt ry. The stat of charge determined only by the charge integration method will have error due to gassing in the battery and change in battery capacity arising from corrosion of th electrode plates and shedding of active mat rial. Th refore, th monitor uses this charge integration method from th instant of the starting of the car until a preset limit of time, preferably two hours, elapses from the time the engine is switched off. As the skilled practioner in the art will appreciate, the combination of the two methods described above offers accurate value of the state of charge of the automotive battery.

In step 5 the vehicle status is determined. If the vehicle is in the starting process, the monitor follows the path beginning with step 6 in branch A. Otherwise, branch B beginning with step 13 is followed when the engine is running and route C with step 19 is followed when the engine is off.

In route A, the monitor measures the parameters V, I and t repeatedly in steps 7 and 8 until the vehicle engine has started or the driver has stopped the cranking process. The monitor can recognize the status of the starting process from the sign and value of the current I. Practioners of the art recognize that the starting process can be identified in several other ways as for example from the starting switch. If the vehicle engine has started, the monitor continues at step 9; otherwise control is transferred to step 3 again. In step 9, the monitor measures the recharge current, battery voltage and the power source voltage for a predetermined period of time, preferably 5-10 minutes. If the vehicle engine is switched off in the meantime, the monitor will go to step 3. In step 10, using the measurements during the starting process, the monitor determines the internal resistance (IR) and polarization (P_R).

In accordance with this invention, the internal resistance of a SLI battery can be determined from the instantaneous change in voltage at the beginning and at the end of a current input to or output from the battery. The skilled practioner in the art will appreciate that there are numerous ways of achieving this, as for example, using any of the accessories for a discharge pulse current or the power source of the car for a charge pulse current. According to the invention, the internal resistance of the automotive battery is determined from its open circuit voltage (OCV), the first measured voltage (V_s) and the initial current (I_s) that flows from the battery to the starter load during the starting process as illustrated in Figure 4, and according to the equation 2:

$$IR = (OCV - V_s)/I_s \quad (2)$$

The maximum instantaneous power the automotive battery can output is inversely related to its internal resistance. Thus according to this invention, the battery's power output capability is determined from the internal resistance.

The battery polarization resistance (P_R) arises from nonuniformity in electrolyte concentration in the electrode to the bulk of the electrolyte between the plates. It is determined from the above parameters, V_s and I_s and the battery voltage after a predetermined time interval or the last voltage reading (V_l) during the starting process according to the equation:

$$P_R = (V_s - V_l)/I_s \quad (3)$$

It is appreciated that the internal resistance and polarization can be determined as frequently as desired making use of the starting or switching off of the car engine or switching on or off of any accessory in the automobile.

One of the important aspects of the invention is its ability to predict the low temperature limit up to which the battery would be able to start the car. The temperature dependence of the starting power requirements of an automobile and the temperature dependence of the power output capability of the corresponding recommended size battery are illustrated in Figure 5 in terms of the battery's internal resistance (IR). The IR is inversely proportional to the battery's maximum output power. It is clear from Figure 5 that the battery can easily meet the required starting power at high temperature region of the normal usage temperature range. As the ambient temperature decreases, as for example in winter season, the battery's output power decreases and the car's required starting power increases. According to this invention, the car cannot be started below the temperature where these two curves cross.

In accordance with the findings of this invention, the dependence of power requirements of various cars and the corresponding recommended battery's power output may be generalized and described as in the curves illustrated in Figure 6. At temperatures around -30°C, the power output capability of the battery is only half of that at 27°C, whereas the power required to start the car at this low temperature is two times the power required at 27°C.

Next in step 10, the monitor then calculates the internal resistance of the battery at other temperatures using the IR determined in step 10, the temperature measured in step 3 and the relationship in curve B of Figure 6. Similarly, the acceptable limits of IR at various temperatures are calculated using the data in curve A of Figure 6, if the acceptable IR limit is known at any one temperature. This acceptable IR limit is calculated from the power requir m nts of the starting motor load which, in turn d pends on the siz and mod l of the ngine. These power data can b obtained from th automobile manufacturer for one or more t mperatures. Alternately, the monitor can determin th se data in st p 11 from its xperi nc during th first we k of its operation. For exampl , the monitor can measure the ambient temperature (step 3) and the current delivered by th bat-

tery during the starting proc ss for th first few pres t number of startings, and d termin th acc ptabl IR limit in each cas at a particular pr set temperature, as for exampl 27°C, using the curve A in Figur 6. The monitor then takes the av rage of th s values as th engine starting r quirement at that preset t mp rature. Using these two sets of data in relative t rms, e.g., in percentage, curv s A and B, illustrated in Figure 6, the monitor calculates the absolute data such as in Figure 5. The monitor then determines the temperature at which the two curves in Figure 5 cross. This represents the temperature at which the battery's power output capability matches the power requirements of the starting motor.

All automotive batteries are rated in what is known as Cold Cranking Amperes (CCA) in the trade. In accordance with this invention, the battery's room temperature acceptable internal resistance limit (in milliohms), e.g., 27°C, multiplied by the rated CCA (in amperes) seems to be constant, around 37,800. This is true for all vehicles which use a 6 cell 12 volt lead acid battery system. Therefore the limit IR is obtained as follows:

$$\text{limit IR} = (37,800/CCA) \quad (4)$$

Practioners of the art appreciate that this constancy number would be different for different temperatures and any particular temperature can be used.

Next in step 12, various diagnostics are performed using the data collected during starting and recharging the battery right after starting. Those include maintenance requirements, as for example, cleaning terminals and adding water. A preferred version of the monitor recognizes maintenance needs as they arise and advises the driver accordingly. Soon after a battery, such as lead acid battery, is discharged or charged, the voltage measured across the battery terminals changes even though the battery is in open circuit, due to the nonuniformity of the electrolyte concentration in the pores of the electrodes and the bulk, normally known as concentration polarization. According to this invention, as the electrolyte level decreases, the polarization as defined in equation 3 increases. However, the polarization is also large when the state of charge is low though the electrolyte level is adequate. The monitor distinguishes between these two conditions by examining the state of charge determined earlier in step 4.

With the extensive use of maintenance free batteries in recent times, cleaning corroded terminals has become the most common maintenance problem for the automotive battery. As the battery terminals corrode with time, the resulting lead compounds (oxide and sulfate) on the terminals cause a substantial increase in resistance at the terminal to wire connection. The high resistance leads to a large voltage drop reducing the power available for the starter motor. This often results in inability to start the car. The preferred version of this invention can detect this problem as it arises and warn the user in advance. The positive and negative battery voltage sensing wires are fused with the battery's positive and negative lead wires respectively near the end of the wires connecting to the battery terminals. Therefore, the internal resistance determined by the monitor includes all resistance from positive lead wire end to negative lead wire end including the contact resistance between the wires and the battery terminals. The battery internal resistance remains within a narrow range as long as the state of charge is above 70% and the battery has not lost capacity substantially. A preferred embodiment of this monitor advises the driver to clean the terminals when the determined internal resistance is larger than a predetermined value, as for example, more than twice the initial internal resistance of the battery at a preset temperature.

A primary objective of this invention is to advise the driver of the necessity to change the battery before it becomes weakened to an extent that it cannot deliver the required power. All batteries, as for example the automotive lead acid batteries, lose capacity with age due to shedding of the active material and, irreversible change and unrechargeability of part of the active material. This is reflected in its internal resistance which correspondingly increases with age. A preferred embodiment of this invention, when it identifies larger than a preset limit of internal resistance of the battery, lower than a preset percentage of original capacity and a state of charge higher than 80%, advises the user to change the battery. The monitor also advises to change the battery when it detects a soft shorted cell or mismatched capacity cell. The procedure how it detects these situations will become clear in later steps.

After step 12, the control is transferred sequentially to step 21 wherein all parameters and variable values are stored in memory, steps 22, 1, 2 and 3. In commercial device, the control will be transferred to step 3 from step 12 due to the continuous operational loop. After passing through steps 4 and 5, when the engine is on and running, route B is followed.

A preferred embodiment of this invention can also save energy by providing a control output to trigger the alternator on/off depending upon the battery status and vehicle operating conditions. Typically the battery is maintained between a preset low limit, as for example 80%, and 100% state of charge (SOC). The alternator may b disconnected or disengag d from the driv through a clutch, or the field current cut-off whenever the battery reaches 100% SOC. Until the SOC falls to the preset low limit, e.g., 80%, the battery will meet all the pow r n eds of th car. At th low limit of SOC, th alternator will b made operational again until the battery is fully charged, i. ., SOC=100%. However, when the power requirement in the car exceeds a certain preset

limit, or the ambi nt temp rature is below a preset limit, the alternator will be left in operational on position even if th SOC is above th preset limit. This situation may arise when the car is driven in night time or winter season and also when the air conditioner is on. Similarly, the alternator will b op rational each time the car is started until the battery is fully charged. Typically this may take five to ten minut s after the start of the car. Control of the alternator is expected to lead to a long life for the battery since the continuous severe charging conditions and gassing experienced by the battery during overcharge are virtually eliminated.

Next in step 14, the monitor checks whether the alternator is required to be on according to the criteria discussed in the previous paragraph. If it should be on, the route B-1 starting with step 15 is followed; otherwise, the route B-2 with step 18 is followed. In step 15, the alternator is switched on or kept on if it is already on. In step 16, the monitor determines whether the driver has indicated the need for a test cycle. In the next step (17), a special battery test cycle is performed if the driver desires. The car engine should be on continuously and should remain at or above a minimum speed in revolutions per minute (RPM) so as to obtain a preset minimum output power from the power source, i.e., alternator/regulator at least for a few minutes in order to be able to complete the test cycle successfully. Typically this would be done in rural driving or highway driving unless the output power from the power source is high enough even during engine idle speed. Otherwise, the test cycle would be aborted. In a preferred version of this invention, the driver would press a button or other means to indicate the desirability of this test. The monitor then charges the battery to 100% SOC, isolates the battery for a preset period and performs the test.

In a preferred embodiment of the invention, the test cycle involves imposing a linearly increasing current or voltage ramp onto the battery terminals and measuring the corresponding voltage or current response of the battery as illustrated in Figure 7. Typically, the current signal consists of an increasing ramp from 0A to a preset limit in a preset time interval, holding constant at this value for a preset interval, and a decreasing ramp from this preset level to 0A in the same preset time interval. For example the current may be increased from 0 to 20 A in 60 seconds, held at this level for 5 seconds, and decreased from 20 to 0 A in 60 seconds. It is obvious to those in the art that the current output of the power source will be continuously adjusted by the monitor such that the required current for the battery test is available at any instant during the test. When the voltage ramping is used, the signal consists of an increasing ramp from the open circuit voltage (OCV) to an end voltage which is higher than the OCV by a preset limit, as for example, 3 V higher than the OCV, in a preset time interval, and decreased from this level to the OCV in the same preset time interval. In both current ramping and voltage ramping methods, the increasing signal reverts over to the holding portion before the preset time limit is exceeded, whenever a preset voltage limit, e.g., 2.6 V/cell, is reached. The presence of a maximum in dV/dI versus I_{ramp}, or a minimum in dI/dV versus V_{ramp} indicates the gas point. From the voltage at the gas point, the number of cells (NOC) is calculated using the following formula:

$$NOC = V_{gas}/2.5 \quad (5)$$

In an automotive battery this would normally be 6. Any other number is indicative of a defective battery. The current at which the gas point occurs in the ramp up direction, $I_{gas\text{-}up}$ is proportional to the battery capacity as illustrated in Figure 8. The current at which the gas point occurs in the ramp-down direction, $I_{gas\text{-}down}$, reaches the lowest possible value, typically around 0.8 A, when the battery is fully charged. Thus, the state of charge can be determined from the $I_{gas\text{-}down}$ parameters.

Batteries with mismatched cells give rise to two or more gas points in the ramp up and ramp down directions. Soft-shorted cells exhibit an inflection in dV/dI at very early stages of the ramp. The presence of sulfated cells give rise to an inflection in the ramp-up direction, but no corresponding inflection in the ramp-down direction. The battery status monitor can, thus, determine several battery defects which are often missed by even skilled mechanics.

Sometimes there are early indications of an imminent battery failure. Near the end of its useful life, some cells, especially the end ones, in the battery start losing capacity at different rates. This results in multiple gas points as indicated by the presence of plurality of inflections in dV/dI in both ramp-up and ramp-down during the test cycle, indicating the presence of mismatched cells. When the monitor detects mismatched cells with their capacities differing by more than a preset limit or the capacity of the weakest cell is lower than the preset limit, or if it detects the existence of a soft short in the automotive battery, the monitor warns the use of the necessity to change the battery.

In route B-2 step 18, the monitor switches off or disengages the alternator or keeps it off if it is already off. After step 18 in route B-2 and also after step 17 in route B-1, the control is passed to step 3 in a similar way to the transfer of control to step 3 after step 12 in route A. When the monitor detects the car engine off in st p 5, it follows route C. In this route in step 20, it checks the discharg current from the battery. If the battery output current is more than a preset limit, as for xample when th cabin light or head light or hood light is on, th monitor warns th user of the xcessiv l akag current. If th battery drain current is more than a preset limit and the accessori s are all of, th monitor warns of the existence of short circuit in the el ctrical circuitry

of the automobil . The monitor also indicates the existence of a soft short in one of th cells of the battery on detecting an open circuit voltage of the battery lower than a preset limit, when the car ngin is off and there is no excessive current drain through the accessories. The monitor, th n, suggests immediate replac ment of the battery.

5   Figure 3 is a basic block diagram of an apparatus capable of carrying out the method of this invention. It will be understood by those skilled in the art that the actual electrical circuitry of the automobile is more complicated than the circuit shown in Figure 8 incorporating additional accessories and sensors and may be leaving out some of the actuators and shunts; nevertheless the automotive circuit can be reduced to this form. The battery(1), current sensing shunt(6), a microprocessor controlled starter switch(8) and a resister representing
10   starter motor load(2) makes up the starting circuit. A resister forming the accessory load(3) represents the accessories, such as lighting, ignition, air conditioner and other appliances in the car. This load, in series with a microprocessor controlled switch(10) and a current sensing shunt(7), could be powered by either the battery through the switch(9) or by the power source(4), i.e., alternator/regulator, through another microprocessor controlled switch(11). The output voltage of the power source and the battery's state of charge determine which
15   one of them provides power at a given time. The diode 5 prevents the battery from discharging into the power source when it is off. Whenever the battery is to undergo a test cycle, it is isolated from the rest of the electrical circuit using switches 8 and 9 for a few minutes before the test. The power source provides all the power for accessories in this time interval. During the test, switches 9, 10 and 11 remain closed. It will be appreciated that more elements can be added to the circuit to measure additional parameters as, for example, another shunt
20   between the elements 4 and 11 or between the elements 2 and 8. Similarly, additional switches and accessories can be incorporated.

Example 1

25   Determination Of The Internal Resistance And Polarization Of An Automotive Battery

An automotive battery of 650 cold cranking amperes (CCA) was placed in a Tenney environmental chamber and subjected to a large pulse current discharge at 25°C through a copper coil load which is equivalent to a starting motor load of an automobile for which this battery is recommended. The battery status monitor determined the internal resistance (IR), and polarization of the battery at 25°C to be 7.4 and 1.6 miliohms re-
30   spectively. A similar experiment with the battery at 0°C showed the IR to be 9 mohms.

Example 2

Determination Of Limit IR
35   The monitor determined an acceptable upper limit for the internal resistance (limit IR) of the above battery in Example 1 using its cold cranking amperes (CCA) rating using the equation 4. This value was 58 ohms at 25°C.

Example 3
40

Determination Of Low Temperature Limit
The monitor extrapolated the battery limit IR value and the actual internal resistance of the battery, used in Examples 1 and 2, at 25°C to low temperatures and determined the low temperature limit for startability of the car. This value was -38.7°C. A similar experiment with the battery at 0°C showed a reliable temperature
45   limit of -38.3°C. This indicates that whatever is the ambient temperature, the low temperature limit can be determined accurately.

Example 4

50   Testing Batteries Of Different Size
Tests, as in Examples 1, 2 and 3 with batteries rated 630, 525, 475, 400 and 340 CCA, at 0 and 25°C determined the reliable low temperature limit and the internal resistances as shown in Table 1.

55

Table 1. Automotive Battery Testing With The Monitor

CCA (A)	Ambi nt Temperature (°C)	Limit IR (mOhms)	Measured IR (mOhms)	Reliable Temp Limit (°C)
650	25	58	7.4	-38.7
	0		9.0	-38.3
630	25	60	8.1	-37.3
	0		10.0	-35.9
525	25	72	11.4	-32.5
	0		13.7	-32.7
475	25	80	8.6	-42.6
	0		10.1	-42.6
400	25	95	10.7	-41.3
	0		12.7	-41.4
340	25	111	13.1	-44.3

Example 5

Determination Of The State Of Charge

The state of charge (SOC) of the battery in example 1 was determined by the monitor at different known levels of SOC. The battery was discharged for known intervals at a predetermined current. The net charge that went into or out of the battery was measured and added to or subtracted from the predetermined battery capacity respectively. From this value, the SOC of the battery was calculated which compared well with the value determined by the monitor.

An automotive battery was almost completely discharged and left for a day without re-charge. It was then connected to the monitor. The monitor detected the battery's very low state of charge and indicated the need for a full charge. It also displayed that the battery was sulfated.

In tests with another partially discharged battery (SOC<40%), the reliable temperature limit was shown to be higher than 35°C. The ambient temperature of the battery during this test was only 20°C which meant the car could not be started without charging. Indeed, the power output of the battery was lower than the power required by the load at 20°C.

Example 6

Evaluation Of The Battery Capacity

The capacity of the battery in example 1 was determined through a test cycle by the monitor. The battery capacity determined by the monitor compared well with the battery manufacturer's data. The monitor advised to change the battery when it detected half or less of the original capacity under fully charged condition, high internal resistance (twice the initial internal resistance at 25°C), and high reliable temperature limit when no other problem regarding the battery is detected.

Example 7

Testing The Presence Of Mismatched Cells

An old battery with known mismatched cells was connected to the battery status monitor and subjected to a test cycle. The monitor detected the presence of mismatched cells and displayed a warning indicating the same and advised to change the battery.

Example 8

Test Of The Gas Saving F ature

Th automotiv battery in Exampl 1 was connect d to the monitor and the starter switch in th simulation electrical circuit was switched on. The monitor determined the battery characteristics during the starting proc- ss and r charged th battery to 100% SOC. It determined the status of the batt ry and the pow r sourc . The monitor switch d off the power source after the battery reached full charge. The battery provid d all the power needs of the car. When the battery's SOC fell to 80%, the power source was switched on again. Thus the monitor controlled the battery's SOC between 80 and 100% by switching on and off the power source.

Example 9

Low Levels Of Electrolyte

A fully charged automotive battery with its electrolyte level at its "full" mark was tested with the monitor for its characteristics. A portion of the electrolyte was withdrawn from the battery until the electrolyte level was just at the top of the electrode plates. The battery was tested again with the monitor. This was repeated with the electrolyte level at 3/4, 1/2 and 1/4 of height of the plates. The internal resistance, polarization and the reliable low temperature limit were determined in each of these tests and given in Table 2.

Table 2. Battery Characteristics As A Function Of Its Electrolyte Level

Electrolyte Level	Internal Resistance	Polarization (Equation 2)	Reliable Temp limit
Full	9.05 mOhm	1.30 mOhm	-32.4°C
Top of plate	9.42	1.31	-33.0
3/4th plate	9.80	2.13	-31.8
1/2 plate	12.91	2.68	-24
1/4th plate	24.17	2.94	-5.9

At electrolyte levels below the top of the plates, higher values of internal resistance, polarization and reliable temperature limit were observed. Thus whenever the monitor detects large values for these parameters cou- pled with good state of charge and capacity, the monitor advises to add water.

Example 10

Corroded Terminals

A fully charged automctive battery's positive terminal was coated with a thin layer of lead sulfate in dilute sulfuric acid with a brush and allowed to dry. Then it was connected as usual to the monitor and the simulation circuit shown in Figure 3. The internal resistance, polarization and the reliable low temperature limit during the tests under good and corroded terminal conditions are shown in Table 3.

Table 3. Characteristics Of An Automotive Battery With Corroded Terminals

Terminal Status	Internal Resistance	Polarization (Equation 3)	Reliable Temp Limit
Normal	8.80 mOhm	1.36 mOhm	-35.3°C
Corroded	16.46	0.48	-18.9

When th monitor det cted a larg internal r sistance, but no significant polarization, normal lev ls of capacity

and stat of charg , it advised to clean the terminal.

Example 11

5   Test Of A 630 CCA Battery At Various Temperatures
        A 630 CCA SLI battery of the size recommended for an Oldsmobile Firenze 2 litre engine car was attached
    to the battery status monitor and tested at various ambient temperatures in a Tenney environmental chamber.
    The acceptable IR limit corresponding to the starting power requirements of the car were calculated accordingly
    by the monitor. The reliable low temperature limits indicated by the monitor are shown in Table 4.

10

Table 4. Test Results Of A 630 CCA Battery
Oldsmobile Firenza 2 Litre Engine

Limit IR	Test Temperature	Predicted Temperature
60 mOhm	25 C	-36.9C
	10	-36.6
	0	-36.0
	- 5	-34.5
	-13	-35.2
	-25	-33.0
30	-25	-18.5
	10	-18.0
	0	-17.2
	- 5	-16.0
	-13	-17.1
	-25	-15.3

They are consistent irrespective of the battery temperature. For the purpose of testing the monitor, a second
series of tests were carried out assuming the power needs of the car to be two times the normal value. (This
is reflected in the acceptable limit of the IR in Table 4, i.e., half of the original value.) Again, as expected, a
35   higher but consistent value of the reliable low temperature limit was observed for all ambient temperatures.
        Example 12
    Test Of A 525 CCA Battery At Various Temperatures
        Similar test results with a 525 CCA battery recommended for a Cutlass Ciera 2.8 litre engine car are shown
    in Table 5.

Table 5.   Test Results Of A 525 CCA Battery
Cutlass CIERA - 2.8 Litre Engine

Limit IR	Test Temperature	Predicted Temperature
72 mOhm	25 C	-32.5 C
	10	-32.6
	0	-32.7
	- 5	-31.4
	-13	-32.9
	-25	-30.2
36	25	-13.8
	10	-13.5
	0	-14.2
	-5	-12.3
	-13	-14.5
	-25	-11.6

The monitor tested the battery characteristics as discussed before and operated successfully. The results are similar to the results of Example 11.

Claims

1. A battery condition monitoring apparatus for providing status and advice concerning a storage battery (1;108) in a motor vehicle, comprising:
    (a) microprocessor means (100) located on said vehicle for controlling the operations of said apparatus;
    (b) software means for instructing said microprocessor means to control the sequence of said operations; and
    (c) memory means connected to said microprocessor means for storing said software instructions and predetermined relationships between the internal resistance of said battery, the tolerable limit of said internal resistance and the ambient temperature of said battery;
    (d) digital to analog converter means (102) connected to said microprocessor means for converting digital signals (104) from said microprocessor means to analog signals;
    (e) direct current power generator means (106), connected to said digital to analog converter means (102) for producing electric power at voltage and current, required by said microprocessor means;
    (f) current sensor means (6;110), connected to a terminal of said battery (1;108), for measuring the current passing into and out of said battery;
    (g) temperature sensor means, located near said battery, for measuring the ambient temperature of said battery;
    (h) voltmeter means (112) for measuring the voltages of said battery, current sensor, temperature sensor and direct current power generator means;
    (i) analog to digital converter means (122), connected to said voltmeter, for converting the analog signals from the said voltage measurements to digital signals (124) appointed for transfer to said microprocessor;
    (j) actuator means (8,9,10,11) for controlling the electrical circuits connecting said sensors, said direct current power generating means and said battery; and
    (k) display means, controlled by said microprocessor for indicating said battery status and advice;
        characterised by:
    (l) second software means for analyzing said current, voltages and temperature, and for determining the internal resistance (IR) and polarization resistance (PR) of said battery, for determining the state of charge of said batt ry as a function of open circuit voltag (OCV) xcluding polarization effects, for d tecting possibl corroded terminals from said determined state of charge and said internal resistance (IR), calculated according to the relation

$$IR = (OCV - V_s)/I_s \quad (2)$$

where OCV is the open circuit voltage, V_S is the first measured voltage and I_S is the initial current, and for detecting possible low electrolyte level as a function of said polarization resistance (PR), calculated according to the relation

$$P_R = (V_S - V_I)/I_S \quad (3)$$

where V_I is the last voltage reading during the starting process, and said state of charge, whereby said internal resistance of said battery is determined from the instantaneous change in voltage at the beginning or at the end of a current input to or current output from the battery, which instantaneous change in voltage is caused by switching on or switching off charge current to or discharge current from said battery, and said polarization resistance of said battery is determined from a change in voltage during a predetermined time interval immediately following said instantaneous change in voltage, and for determining a low temperature starting limit by comparing said battery's power output capability, determined as a function of the calculated internal resistance, with the prevailing power requirements of said vehicle component system including the starting system and taking account of the temperature of said system.

2. An apparatus according to Claim 1, wherein said storage battery is a rechargeable lead acid battery and said direct current power generating means is an alternator/rectifier/regulator means.

3. A method for monitoring a vehicle storage battery, which comprises the steps of operating apparatus according to Claim 1, to:

(a) measure continuously the ambient temperature, the battery voltage, the output voltage of a power source attached to said battery, and the current to and from said battery;

(b) analyze said current-voltage (I-V) data to determine the internal resistance (I_R) and polarization resistance (P_R) of said battery, whereby said internal resistance of said battery is determined from the instantaneous change in voltage at the beginning or at the end of a current input to or current output from the battery, which instantaneous change in voltage is caused by switching on or switching off charge current to or discharge current from said battery, and said polarization resistance of said battery is determined from a change in voltage during a predetermined time interval immediately following said instantaneous change in voltage;

(c) determine the state of charge of said battery as a function of open circuit voltage (OCV) excluding polarization effects, determining possible corroded terminals as a function of said state of charge and said internal resistance from the relation (2) set out in claim 1, and determining possible low electrolyte level as a function of said polarization resistance from the relation (3) set out in claim 1 and said state of charge;

(d) determine the low temperature starting limit by comparing said battery's power output capability, determined as a function of the determined internal resistance with the prevailing power requirements of said vehicle component system including the starting system and taking account of said ambient temperature; and

(e) indicate data produced by said comparison.

4. A method according to Claim 3, further comprising determining the engine starting power requirements at various temperatures by extrapolating the power actually used by the engine at any one temperature using a predetermined mathematical function or graphical data that relates the battery's power output capability with various temperatures.

5. A method as recited by Claim 4, further comprising the steps of:

(a) subjecting said battery to a special test cycle wherein a predetermined profile of current or voltage is imposed onto the battery by the charging system and the battery response voltage or current is measured;

(b) evaluating the data in the forms, dV/dI versus I, or dI/dV versus V;

(c) determining the battery characteristics, including the capacity, and the voltage as a function of the current and voltage data provided by step (a);

(d) determining the battery defects, including mismatched cells as a function of the corresponding values of current or voltage at which the battery starts evolving gas during the test of step (a), and soft-shorted cells or sulfated cells both as a function of the imposed current; and

(e) indicating said data and advice.

6. A method as recited by Claim 5, wherein the end of useful life of said battery is indicated by the presence

of mismatched cells or soft-shorted c lls.

7. A method as recited in Claim 5, wherein the state of charg is determined from th current at which gas stops evolving in the ramp down direction.

8. A method as recited by Claim 5, wherein the capacity of said battery is determined from the current at which the battery starts evolving gas in said battery in the ramp-up direction.

Patentansprüche

1. Monitorvorrichtung für den Batteriezustand zum Liefern eines Status und eines Rates betreffend eine Speicherbatterie (1; 108) in einem Motorfahrzeug, mit:

(a) einer am Fahrzeug angeordneten Mikroprozessor-Einrichtung (100) zum Steuern der Vorgänge der Vorrichtung;

(b) Software zum Instruieren der Mikroprozessor-Einrichtung, die Abfolge von Vorgängen zu steuern; und

(c) mit der Mikroprozessor-Einrichtung verbundene Speichereinrichtungen, um die Instruktionen der Software und die vorbestimmten Verhältnisse zwischen den Innenwiderständen der Batterie, den tolerierbaren Grenzwert des Innenwiderstandes und die Umgebungstemperatur der Batterie zu speichern;

(d) eine mit der Mikroprozessor-Einrichtung verbundene Digital/Analog-Wandlereinrichtung (102), um die Digitalsignale (104) aus der Mikroprozessor-Einrichtung in Analogsignale umzuwandeln;

(e) eine an die Digital/Analog-Wandlereinrichtung (102) angeschlossene Generatoreinrichtung (106) für Gleichstromenergie, um elektrische Energie mit der von der Mikroprozessor-Einrichtung benötigten Spannung und Stromstärke zu erzeugen;

(f) eine mit einem Anschluß der Batterie (1; 108) verbundene Stromsensoreinrichtung (6; 110) zum Messen des in die und aus der Batterie gehenden Stromes;

(g) eine nahe der Batterie angeordnete Temperatursensoreinrichtung zum Messen der Umgebungstemperatur der Batterie;

(h) eine Spannungsmeßeinrichtung (112) zum Messen der Spannungen der Batterie, am Stromsensor, Temperatursensor und an der Generatoreinrichtung für die Gleichstromenergie;

(i) ein mit dem Spannungsmesser verbundener Analog/Digital-Wandler (122) zum Umwandeln der Analogsignale von den Spannungsmessungen in Digitalsignale (124), die für die Übertragung an den Mikroprozessor bestimmt sind;

(j) eine Betätigungseinrichtung (8,9,10,11) zum Steuern der elektrischen, die Sensoren verbindenden Kreise, der Generatoreinrichtung für die Gleichstromenergie und der Batterie; und

(k) eine vom Mikroprozessor gesteuerte Anzeigeeinrichtung zum Anzeigen des Zustandes der Batterie und eines Ratschlages;

gekennzeichnet durch:

(l) eine zweite Software zum Analysieren des Stromes, der Spannungen und der Temperatur und zum Bestimmen des Innenwiderstandes (IR) und des Polarisationswiderstandes (P_R) der Batterie, zum Bestimmen des Ladungszustandes der Batterie in Funktion der Leerlaufspannung (OCV) unter Ausschluß von Polarisationseffekten, zum Feststellen möglicher korrodierter Anschlüsse aus dem festgestellten Ladungszustande und dem Innenwiderstand (IR), der gemäß der Beziehung

$$IR = (OCV - V_S)/I_S \quad (2)$$

berechnet wird, worin OCV die Leerlaufspannung ist, V_S die erste gemessene Spannung ist und I_S der ursprüngliche Strom ist, und zum Ermitteln möglicher niedriger Elektrolytspiegel in Funktion des Polarisationswiderstandes (PR), der gemäß der Beziehung

$$P_R = (V_S - V_I)/I_S \quad (3)$$

berechnet wird, worin V_I die letzte Spannungsablesung während des Startvorganges ist, und dem Ladungszustande, wodurch der Innenwiderstand der Batterie aus der momentanen Veränderung der Spannung am Beginn bzw. am Ende einer Stromzufuhr in oder einer Stromabfuhr aus der Batterie festgestellt wird, welche momentane Veränderung der Spannung durch das Einschalten oder Ausschalten des Ladungsstromes zur bzw. des Entladungsstromes aus der Batteri v rursacht wird, und wobei der Polarisationswid rstand der Batteri aus der Veränderung der Spannung während eines vorbestimmten Z itintervalles bestimmt wird, der der V ränderung der Spannung unmittelbar folgt, und zum Bestimm n ein s Startgrenzw rtes bei niedrig r Temperatur durch V rgleich d r in Funktion d s rrech-

15

neten Inn nwid rstandes bestimmten Fähigkeit d r Batterie zur Energi abgabe mit den vorherrschenden En rgieanforderungen des Komponentensystems des Fahrzeuges, einschließlich des Startsyst ms, wobei die T mp ratur des Systems berücksichtigt wird.

2. Vorrichtung nach Anspruch 1, bei der die Speicherbatterie eine wiederaufladbare Blei-Säure-Batterie ist und die Generatoreinrichtung für die Gleichstromenergie eine Einrichtung mit einem Alternator, einem Gleichrichter und einem Regler ist.

3. Verfahren zum Überwachen der Speicherbatterie eines Fahrzeuges, welches die folgenden Schritte des Betriebes der Vorrichtung nach Anspruch 1 umfaßt:

(a) fortlaufendes Messen der Umgebungstemperatur, der Batteriespannung, der Ausgangsspannung einer mit der Batterie verbundenen Energiequelle und des Stromes zur und aus der Batterie;

(b) Analysieren der Daten von Strom und Spannung (I-V), um den Innenwiderstand (IR) und den Polarisationswiderstand (P_R) der Batterie festzustellen, wodurch der Innenwiderstand der Batterie aus einer momentanen Veränderung der Spannung am Beginn bzw. am Ende einer Stromzufuhr in oder einer Stromabfuhr aus der Batterie festgestellt wird, welche momentane Veränderung der Spannung durch das Einschalten oder Ausschalten des Ladungsstromes zur bzw. des Entladungsstromes aus der Batterie verursacht wird, wobei der Polarisationswiderstand der Batterie aus der Veränderung der Spannung während eines vorbestimmten Zeitintervalles bestimmt wird, der der Veränderung der Spannung unmittelbar folgt;

(c) Bestimmen des Ladungszustandes der Batterie in Funktion der Leerlaufspannung (OCV) unter Ausschluß von Polarisationseffekten, Feststellen möglicher korrodierter Anschlüsse in Funktion des festgestellten Ladungszustandes und des Innenwiderstandes aus der in Anspruch 1 dargestellten Beziehung (2), und Feststellen möglicher niedriger Elektrolytspiegel in Funktion des Polarisationswiderstandes aus der in Anspruch 1 dargestellten Beziehung (3) und dem Ladungszustand;

(d) Bestimmen eines Startgrenzwertes bei niedriger Temperatur durch Vergleich der in Funktion des ermittelten Innenwiderstandes bestimmten Fähigkeit der Batterie zur Energieabgabe mit den vorherrschenden Energieanforderungen des Komponentensystems des Fahrzeuges, einschließlich des Startsystems und unter Berücksichtigung der Temperatur des Systems; und

(e) Anzeigen der durch den Vergleich erzeugten Daten.

4. Verfahren nach Anspruch 3, welches ferner die Ermittlung der Energieerfordernisse für den Start des Motors bei verschiedenen Temperaturen durch Extrapolieren der bei irgendeiner Temperatur vom Motor gebrauchten Ist-Energie unter Anwendung einer vorbestimmten mathematischen Funktion oder graphischer Daten umfaßt, die mit der Fähigkeit der Batterie zur Energieabgabe bei verschiedenen Temperaturen in Beziehung stehen.

5. Verfahren nach Anspruch 4, welches ferner die folgenden Schritte umfaßt:

(a) Unterwerfen der Batterie unter einen speziellen Testzyklus, bei dem der Batterie vom Ladesystem ein vorbestimmtes Profil des Stromes oder der Spannung aufgeprägt und die Ansprechspannung bzw. der Ansprechstrom der Batterie gemessen wird;

(b) Auswerten der Daten in Form von dV/dI über I oder dI/dV über V;

(c) Bestimmen der Batterieeigenschaften einschließlich der Kapazität und der Spannung als Funktion der durch den Schritt (a) gelieferten Strom- und Spannungsdaten;

(d) Feststellen der Batteriedefekte, einschließlich einer Nichtübereinstimmung der Zellen in Funktion der entsprechenden Werte von Strom bzw. Spannung, bei dem bzw. der die Batterie beginnt, während des Tests von Schritt (a) Gas zu entwickeln, sowie weichgeschlossene Zellen oder sulfatierte Zellen jeweils in Funktion des aufgeprägten Stromes; und

(e) Anzeigen der Daten und des Ratschlages.

6. Verfahren nach Anspruch 5, bei dem das Ende der nützlichen Lebensdauer der Batterie durch das Vorliegen nicht aufeinander abgestimmter Zellen oder weichgeschlossener Zellen angezeigt wird.

7. Verfahren nach Anspruch 5, bei dem der Ladungszustand aus dem Strom bestimmt wird, bei dem das Gas in Abwärtsrichtung der Rampe aufhört, sich zu entwickeln.

8. Verfahren nach Anspruch 5, b i dem die Kapazität der Batterie aus dem Strom bestimmt wird, bei dem die Batteri b ginnt, in Aufwärtsrichtung der Rampe in der Batterie Gas zu ntwickeln.

Revendications

1. Appareil d surveillance de condition de batterie pour délivr r l'état et d s informations concernant une batterie d'accumulat urs (1;108) dans un véhicule à moteur comprenant :

   (a) un moyen de microprocesseur (100) placé sur ledit véhicule pour commander les opérations dudit appareil;

   (b) un moyen de logiciel pour ordonner audit moyen de microprocesseur de commander la séquence desdites opérations; et

   (c) un moyen de mémoire connecté audit moyen de microprocesseur pour mémoriser lesdites instructions logicielles et des relations prédéterminées entre la résistance interne de ladite batterie, la limite tolérable de ladite résistance interne et la température ambiante de ladite batterie;

   (d) un moyen de convertisseur numérique/analogique (102) connecté audit moyen de microprocesseur pour convertir les signaux analogiques (104) provenant dudit moyen de microprocesseur en signaux analogiques;

   (e) un moyen de générateur de puissance à courant continu (106), connecté audit moyen de convertisseur numérique/analogique (102) pour produire l'énergie électrique à une tension et courant requis par ledit moyen de microprocesseur;

   (f) un moyen de capteur de courant (6;110) connecté à une borne de ladite batterie (1;108) pour mesurer le courant entrant et sortant de ladite batterie;

   (g) un moyen de capteur de température; placé près de ladite batterie destiné à mesurer la température ambiante de ladite batterie;

   (h) un moyen de voltmètre (112) pour mesurer les tensions de ladite batterie, du capteur de courant, du capteur de température et du moyen de générateur de puissance à courant continu;

   (i) un moyen de convertisseur analogique/numérique (122) connecté audit voltmètre pour convertir les signaux analogiques provenants desdites mesures de tension en signaux numériques (124) destinés à être transférés audit microprocesseur;

   (j) des moyens d'organes de commande (8,9,10,11) pour commander les circuits électriques connectant lesdits capteurs, ledit moyen de génération de puissance à courant continu et ladite batterie; et

   (k) un moyen d'affichage, commandé par ledit microprocesseur pour indiquer ledit état de la batterie et les informations; caractérisé par :

   (l) un second moyen de logiciel pour analyser ledit courant, les tensions et la température pour déterminer la résistance interne (IR) et la résistance de polarisation (PR) de ladite batterie afin déterminer l'état de charge de ladite batterie comme une fonction d'une tension en circuit ouvert (OCV) excluant les effets de la polarisation destinés à détecter les bornes corrodées possibles à partir dudit état déterminé de charge et de ladite résistance interne (IR), calculés conformément à la relation

$$IR = (OCV - V_s)/I_s$$

   ou OCV est la tension en circuit ouvert, V_s est la première tension mesurée et I_s est le courant initial, et pour détecter un bas niveau d'électrolyte possible comme une fonction de ladite résistance de polarisation (PR), calculée conformément à la relation

$$P_R = (V_s - V_1)/I_s$$

   ou V_1 est la dernière lecture de tension pendant le processus de démarrage et ledit état de charge, d'où il résulte que ladite résistance interne de ladite batterie est déterminée à partir du changement instantané de tension au commencement ou à la fin d'une entrée de courant ou d'une sortie de courant à partir de la batterie, lequel changement instantané de la tension est provoqué par l'application ou la non-application du courant de charge ou du courant de décharge de ladite batterie, et ladite résistance de polarisation de ladite batterie est déterminée à partir d'un changement de tension pendant un intervalle de temps prédéterminé suivant immédiatement ledit changement de tension instantané et pour déterminer une limite de démarrage à basse température en comparant ladite capacité de sortie en puissance de la batterie déterminée comme une fonction de la résistance interne calculée, aux exigences de puissance prévalantes dudit système de composants du véhicule comportant le système de démarrage et prenant en compte la température dudit système.

2. Appareil selon la revendication 1, dans lequel ladite batterie d'accumulateur est un accumulateur au plomb rechargeabl t ledit moyen d génération de puissance à courant continu est un moyen d'alternateur/redresseur/régulateur.

3. Procédé pour surveiller un batterie d véhicule qui comprend les étap s consistant à m ttr en oeuvre l'appareil s lon la revendication 1 :

a) mesurer n continu la température ambiante, la tension de la batteri , la t nsion de sorti d'un sour-
ce de puissance reliée à ladite batteri   t le courant entrant et sortant de ladite batterie;
b) analyser l sdites données de courant/t nsion (I-V) afin de dét rmin r la résistance intern   (IR) et
la résistance de polarisation (PR)de ladite batterie, d'où il résulte que ladit résistance interne de ladite
batterie est déterminée du changement instantané de tension au commencement ou à la fin d'une en-
trée en courant ou d'une sortie en courant à partir de ladite batterie, lequel changement instantané de
la tension est provoqué par l'application ou la non application du courant de charge ou du courant de
décharge à ladite batterie, et ladite résistance de polarisation de ladite batterie est déterminée à partir
d'un changement de tension pendant un intervalle de temps prédéterminé suivant immédiatement ledit
changement instantané de tension ;
c) déterminer l'état de charge de ladite batterie comme une fonction de la tension en circuit ouvert
(CCV) excluant les effets de la polarisation, déterminer les bornes corrodées possibles en fonction du-
dit état de charge et de ladite résistance interne à partir de la relation (2) énoncée dans la revendication
1 et déterminer les bas niveaux de l'électronique possibles comme une fonction de ladite résistance
de polarisation à partir de la relation (3) énoncée dans la revendication 1 et dudit état de charge.
d) déterminer la limite de démarrage à basse température en comparant ladite capacité de sortie en
puissance de la batterie déterminée comme une fonction de la résistance interne déterminée, aux exi-
gences de puissance prévalants dudit système de composants de véhicule comportant le système de
démarrage et prenant en compte ladite température ambiante ; et
e) indiquer les données produites par ladite comparaison.

4. Procédé selon la revendication 3, comprenant de plus la détermination des exigences de puissance de
démarrage du moteur à diverses températures par l'extrapolation de la puissance actuellement utilisée
par le moteur à toute température quelconque en utilisant une fonction mathématique prédéterminée ou
de données graphiques qui se rapportent à la capacité de sortie en puissance de la batterie à diverses
températures.

5. Procédé selon la revendication 4 comprenant de plus les étapes consistant à :
a) soumettre ladite batterie à un cycle de test spécial dans lequel une courbe prédéterminée de courant
ou de tension est imposée sur la batterie par le système de charge et la tension ou courant en réponse
de la batterie est mesuré ;
b) évaluer les données sous des formes, dV/dI par rapport à I ou dI/dV par rapport à V;
c) déterminer les caractéristiques de la batterie, comportant la capacité et la tension comme une fonc-
tion des données de courant et de tension procurées par l'étape(a);
d) déterminer les défauts de la batterie, comportant les éléments à faible capacité comme une fonction
des valeurs correspondantes de courant ou de tension auxquelles la batterie commence à dégager des
gaz pendant le test de l'étape (a) et des éléments en court-circuit ou des éléments sulfatés tous les
deux comme fonction du courant imposé ; et
e) indiquer lesdites données et informer.

6. Procédé selon la revendication 5, dans lequel la fin de la durée de vie utile de ladite batterie est indiquée
par la présence d' éléments à faible capacité et d'éléments en court circuit.

7. Procédé selon la revendication 5, dans lequel l'état de charge est déterminé à partir du courant auquel
le gaz arrête d'être dégagé dans la direction de la rampe descendante.

8. Procédé selon la revendication 5, dans lequel la capacité de ladite batterie est déterminée à partir du cou-
rant auquel la batterie commence à dégager des gaz dans celle-ci dans la direction de la rampe montante.
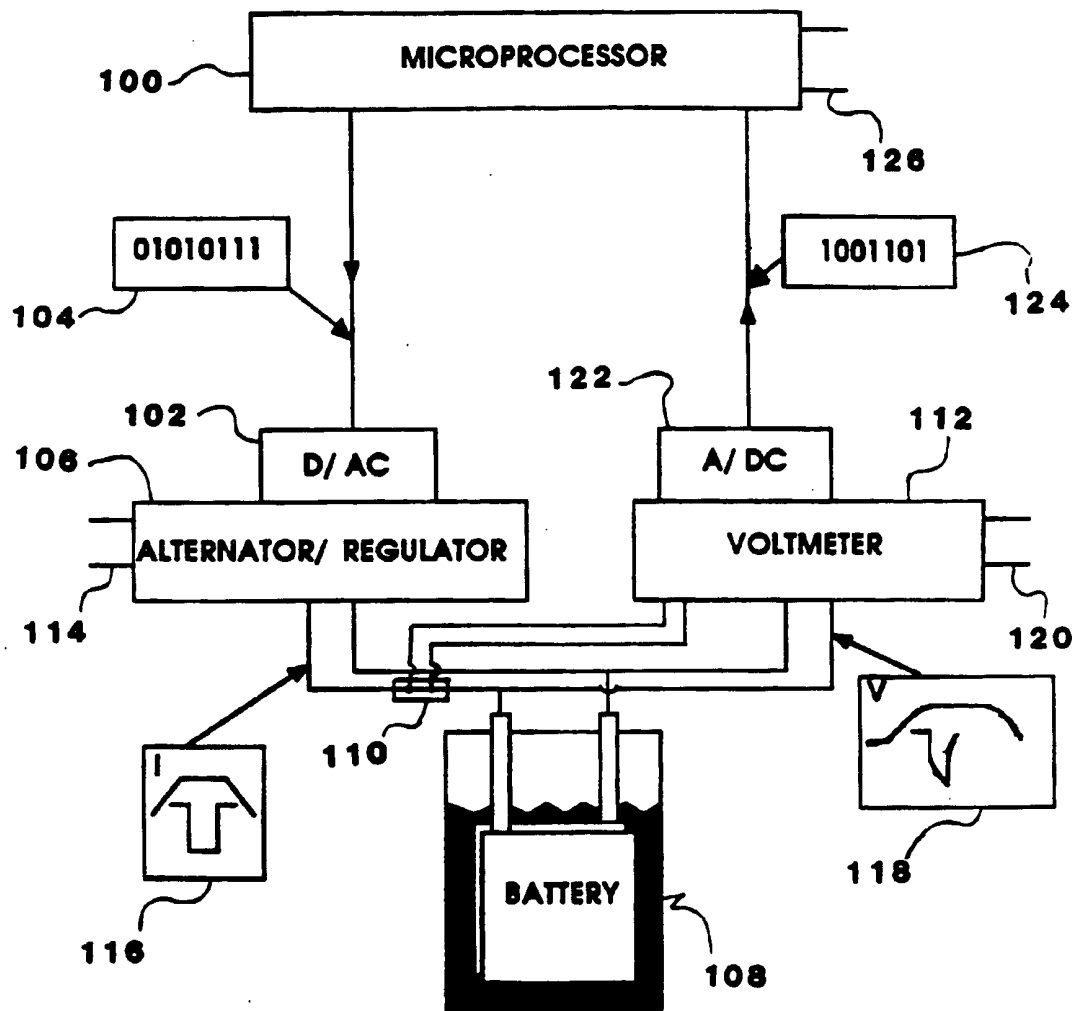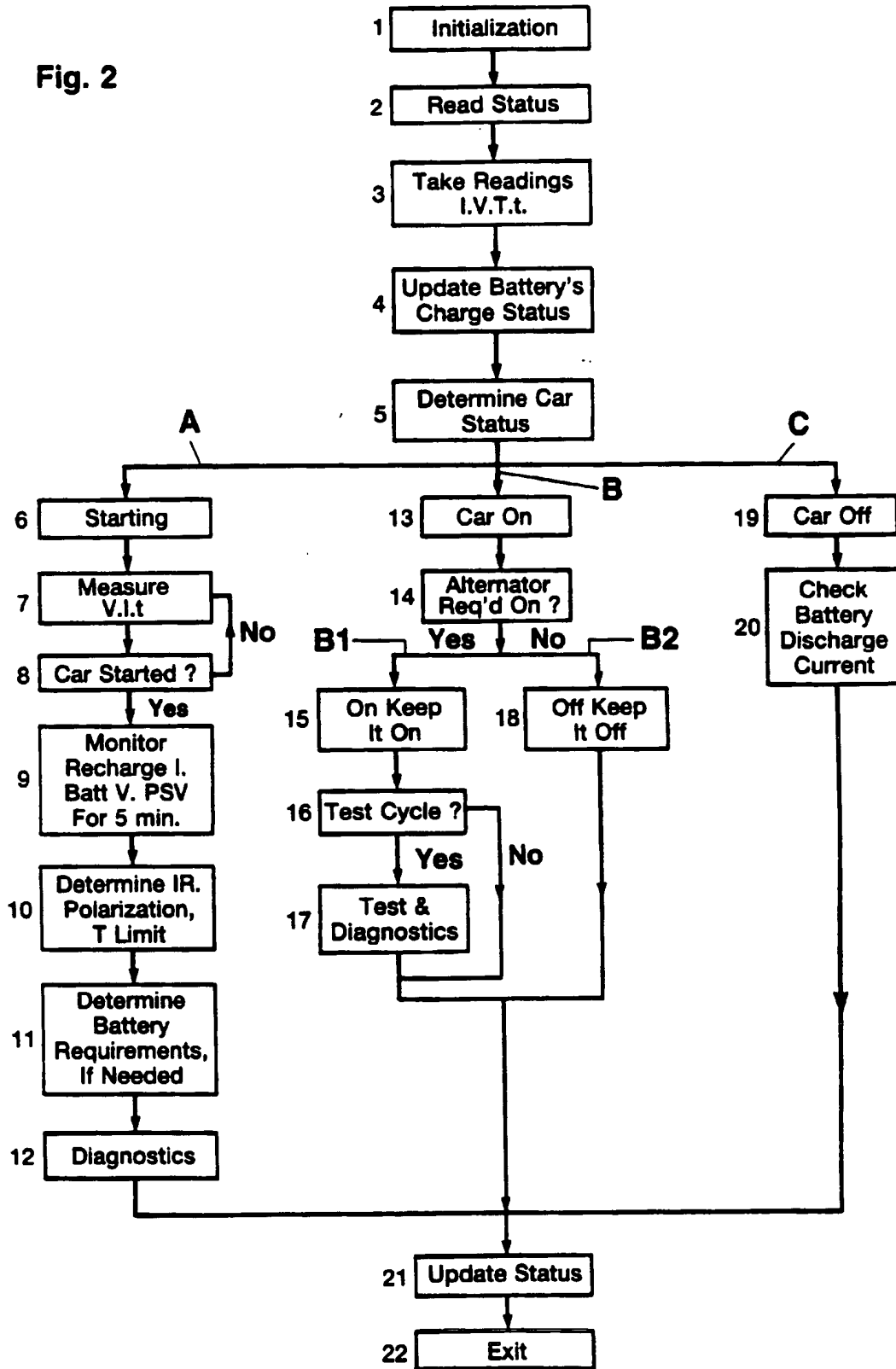
Fig. 1
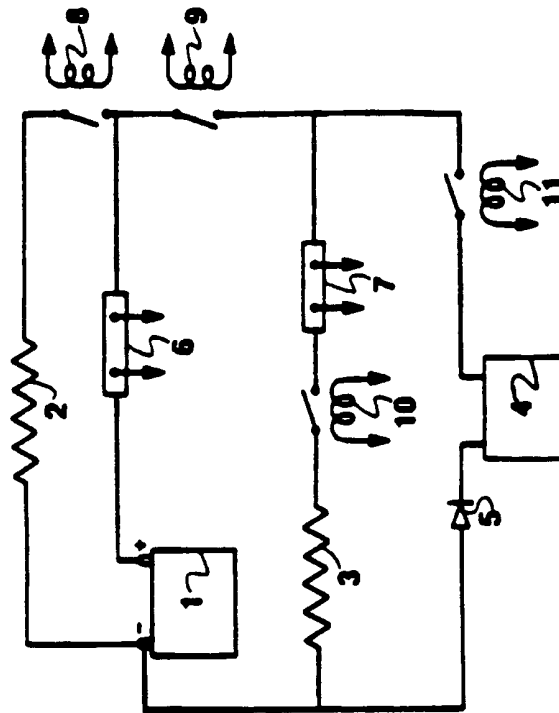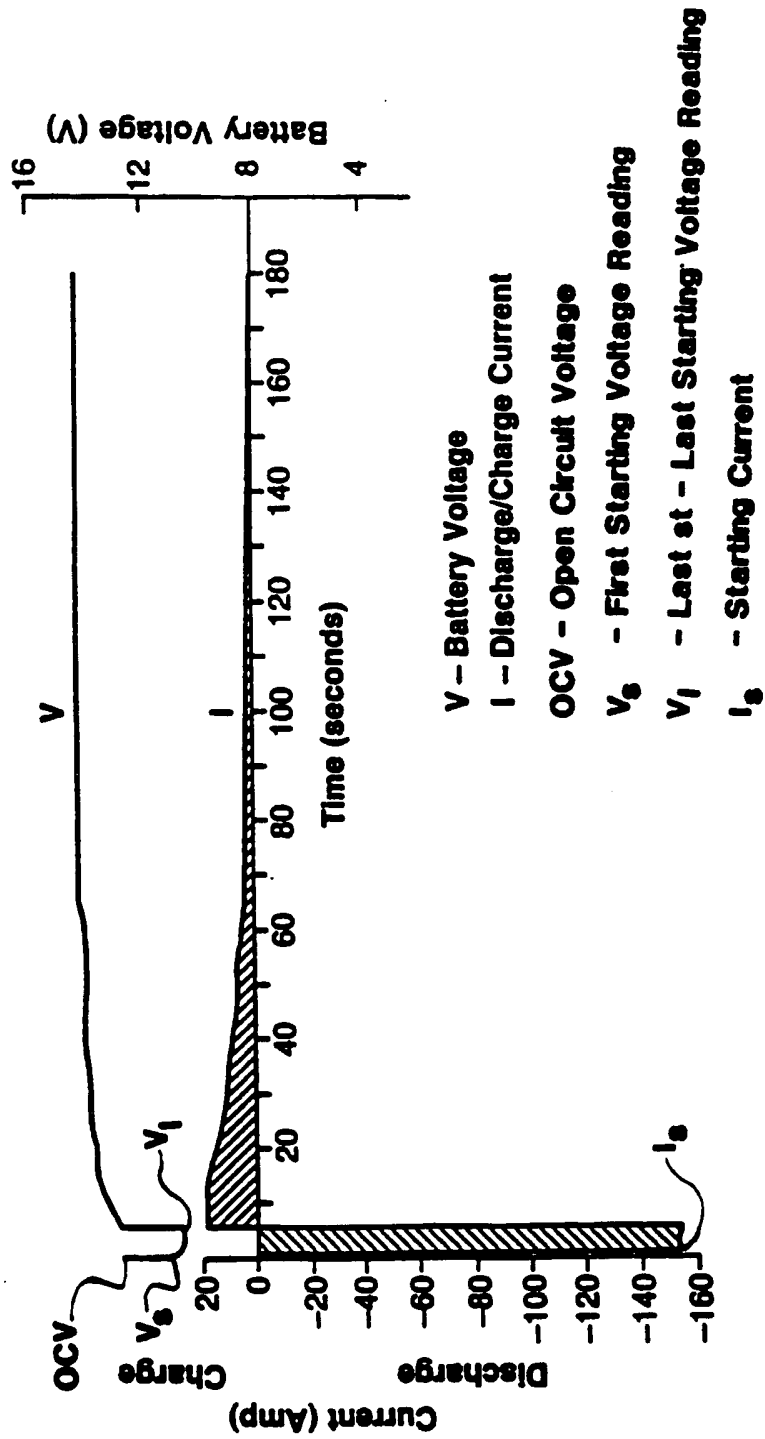
Fig. 2

1 Initialization

2 Read Status

3 Take Readings I.V.T.t.

4 Update Battery's Charge Status

5 Determine Car Status

A

B

C

6 Starting

7 Measure V.I.t

No

8 Car Started ?

Yes

9 Monitor Recharge I. Batt V. PSV For 5 min.

10 Determine IR. Polarization, T Limit

11 Determine Battery Requirements, If Needed

12 Diagnostics

13 Car On

14 Alternator Req'd On ?

B1 Yes No B2

15 On Keep It On

18 Off Keep It Off

16 Test Cycle ?

Yes No

17 Test & Diagnostics

19 Car Off

20 Check Battery Discharge Current

21 Update Status

22 Exit

Fig. 3

Fig.4

V – Battery Voltage

I – Discharge/Charge Current

OCV – Open Circuit Voltage

V_s – First Starting Voltage Reading

V_l – Last st – Last Starting Voltage Reading

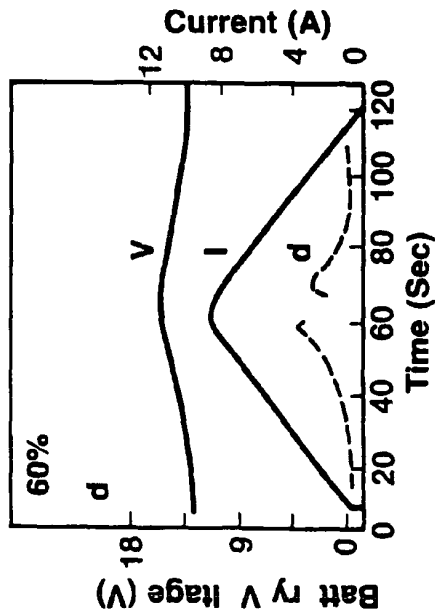I_s – Starting Current

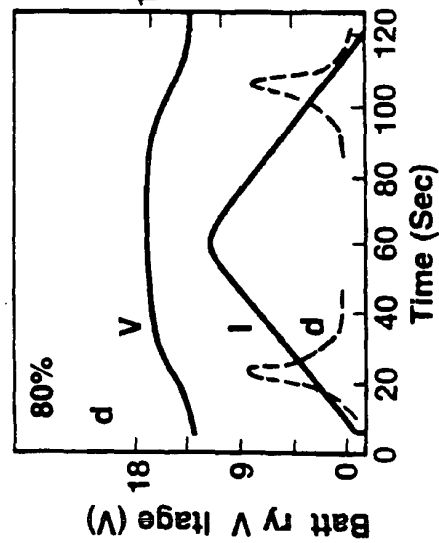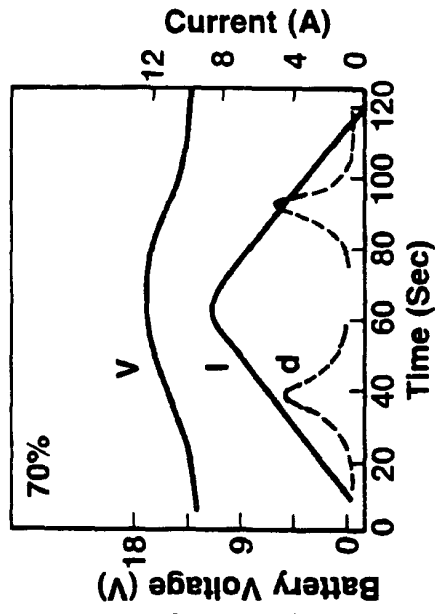**Fig. 5**
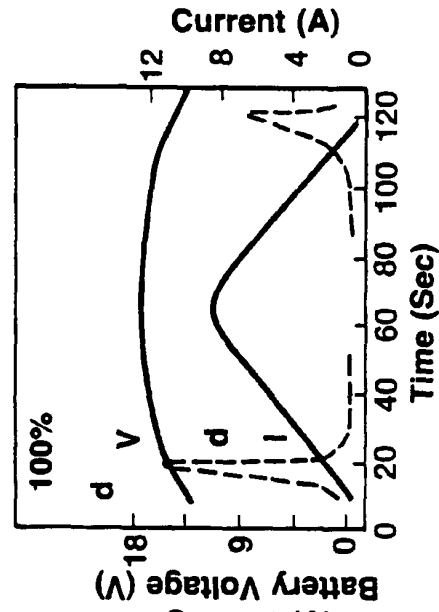

525 CCA Battery

⊙ Limit IR
▢ Actual IR

Fig. 6

V - Response Voltage
I - Applied Current
d - Slope (dV/dt) of V
Battery Details:
    20 Ah Capacity
    6 Cells (Flooded)
Ramping Details:
    Ramp Up - 60 Sec
    Hold - 5 Sec
    Ramp Down - 60 Sec

Fig. 7b

Fig. 7d

Fig. 7a

Fig. 7c

Fig. 8

$$\text{Capacity} = I_{Gas-Up} \times 17.88 - 13.0$$